

**JAPANESE UNEXAMINED PATENT PUBLICATION 8-204558**

(43) Date Laid Open: August 9, 1996

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(51) International Class<sup>6</sup>: H 03 M 1/08, H 03 B 28/00,  
H 03 C 3/00, H 03 M 1/66, 1/86

Identification Symbols and Internal Office Reference

Numbers: F1 ... B, A, A, C

Request for Examination: Not Yet Requested

Number of Inventions: 4 (5 pages in all)

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(21) Application Number: 7-10128

(22) Application Date: January 25, 1995

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(54) Title of Invention

**DA CONVERTER**

(57) Abstract

Object To provide a DA converter which can effectively use higher harmonics generated by sampling, and with few unnecessary spurious signals or noise. Moreover, using this DA converter to provide a signal generator which can generate signals of required frequency with few unnecessary spurious signals or noise.

Constitution A DA converter is realized which effectively uses higher harmonic components generated by means of sampling; extracting the fundamental wave component using a tank circuit 6 from a clock signal applied to the DA converter 2, and corrects the frequency characteristic by multiplying the output signal of the DA converter 2 by this extracted signal. Furthermore, equipping this DA converter 2 with a DDS 7, a signal generator is obtained which can generate signals of a required frequency, with few unnecessary spurious signals or noise, by means of the clock frequency applied to the DA 2 and changing the frequency setting code of the DDS 7.

## Scope of Patent Claims

Claim 1      A DA converter device, wherein it is equipped with DA converter means which convert input digital signals to analog signals, and clock generating means which supply a clock signal to the said DA converter means, and a tank circuit in order to extract n-fold (n being an integer) frequency components of its fundamental wave component from the said clock signal, and multiplying means to obtain a required output signal, multiplying together the output signal of the said tank circuit and the output signal of the said DA converter means.

Claim 2      A signal generator device, wherein it is equipped with digital signal generating means which generates a digital code signal of predetermined frequency corresponding to the applied output frequency setting code, and DA converter means which converts the said digital code signal to an analog signal, and a clock generating means which provides a clock signal to the said digital signal generating means and DA converter means, and a tank circuit in order to extract an n-fold (n being an integer) frequency component of its fundamental wave component from the said clock signal, and multiplying means to obtain a required output signal, multiplying together the output signal of the said tank circuit and the output signal of the said DA converter means.

Claim 3      A signal generator device wherein, in the signal generator device of claim 2, it has means to change respectively the frequency of the said clock signal, and the output frequency setting code in the said digital signal generating means.

Claim 4      An FM modulator which includes the signal generator device of claim 3.

## Detailed Description of the Invention

[0001] Field of Industrial Utilization

The present invention relates to DA converter devices which convert digital signals to analog signals; and to signal generator devices using these DA converter devices; and in addition, to FM modulator devices which include these signal generator devices.

[0002] Prior Art Technology

The prior art technology of DA converter devices which perform correction of aperture distortion, multiplying pulse waves in the output signal of DA converters, is described, for example, in Japanese Patent Application Hei 6-103149. This prior art technology is described hereinbelow, using Fig. 3. Fig. 3 shows the block constitution of this prior art technology. From the digital signal input terminal 1, an n-bit (n being an integer) digital signal is supplied to the DA converter 2. In this DA converter 2, on the other hand, according to the period of a clock signal supplied from a clock generator 5, the said n-bit digital signal is converted to an analog signal. The frequency characteristic of this output signal of the DA converter 2 becomes, for example, the characteristic shown in Fig. 4. Namely, in this Figure, the frequency characteristic of the output signal of the DA converter 2 becomes the frequency characteristic as shown by the full line, with a characteristic aperture effect b (dot-dash line) on the spectrum a of the original analog signal, in a signal spectrum c (broken line) returned for each sampling frequency ( $f_s$ ).

[0003] Here, in the case of positively using the high harmonic components by means of sampling, using up to near the Nyquist frequency ( $f_s/2$ ) as the frequency component of the analog signal, in the prior art, disposing a waveform shaping circuit 8 in order to perform a required waveform shaping treatment on the clock signal generated from the clock generator 5, amplitude distortion was corrected by means of the aperture effect, due to a constitution such as to multiply together in a multiplier 3 the signal which was shaped to the required pulse waveform, and the output signal of the said DA converter 2. Moreover, the constitution is generally used to convert the frequency component f of the output signal of the DA converter 2 to a required frequency band  $f_{cv}$ , as a constitution in order to frequency convert to a required frequency band  $f_{cv}$ , as shown in Fig. 8, causes the generation from a local oscillator 9 of a signal  $f_{LO}$  which has a

frequency which becomes  $f_{cv} - f$  by means of multiplying together, using a multiplier 3, this signal  $f_{LO}$  and the output signal of the DA converter 2.

[0004] Problems to Be Solved By the Invention

As shown in the above prior art, because the constitution shown in Fig. 3 is one in which pulse waveform signals which contain many unnecessary high frequency components are provided in one input of the multiplier 3, unnecessary high frequency components are contained in this pulse wave signal; multiplying the output signal of the DA converter 2, the problem was that the unnecessary frequency components (spurious components) which have to be suppressed are also markedly increased in the output signal of the multiplier 3. Moreover, there is the problem that the high harmonic components contained in the pulse wave also become superposed, via the power supply line or the ground line, on the output signal of the filter 10 and the like disposed in the later stages of the multiplier 3. Moreover, in the frequency converter circuit of the constitution shown in the said Fig. 8, there is the problem that, due to the selection method of the output signal  $f_{LO}$  from the local oscillator 9, spurious components arise in the neighborhood of the signal  $f_{cv}$  after the frequency converter, and cannot be suppressed by the filters of later stages.

[0005] The present invention has as its first object to provide a DA converter from which an output signal is obtained in which, eliminating high frequency components contained in a pulse wave, noise components containing spurious components are markedly reduced. A second object of the present invention is to provide a signal generator containing a frequency converter circuit which can be realized in a comparatively simple constitution, with the possibility of frequency converter to a required frequency band, and also a later stage spurious component-suppressing filter.

[0006] Means to Solve the Problems

The present invention, so as to attain the said first object, is constituted with a tank circuit

inputting clock signals of a DA converter means, in order to extract n-fold (n being an integer) frequency components of its fundamental wave component from the said clock signals, and so as to multiply together the output signal of the said tank circuit and the output signal of the said DA converter means, in order to obtain a required output signal.

[0007] Moreover, in order to attain the said second object, it is equipped with digital signal generating means which generates a digital code signal of predetermined frequency corresponding to the output frequency setting code which was applied, and a DA converter means which converts the said digital code signal into an analog signal, and a clock circuit providing a clock signal to the said digital signal generating means and the DA converter means, and a tank circuit in order to extract an n-fold (n being an integer) frequency component of its fundamental wave component from the said clock signal, and multiplying means to obtain a required output signal, multiplying together the output signal of the said tank circuit and the output signal of the said DA converter means; and in addition, means are disposed in order to respectively change the frequency of the said clock signal and the output frequency setting code in the said digital signal generating means.

#### [0008] Operation

The result is that, as regards the input signal of the multiplier, the output signal of the tank circuit can markedly reduce noise components in the output signal of the multiplier, in order for few noise components of spurious components and the like, compared with the pulse waveform signal of the prior art; also, by a comparatively simple constitution as mentioned above, with low noise, and also by means of aperture effect, a DA converter output signal corrected for amplitude deterioration can be obtained. Moreover, using this DA converter device, a signal generating device can be realized with low noise, and also can generate a required frequency signal.

#### [0009] Embodiment Example

An embodiment example of the DA converter device of the present invention is described hereinbelow with reference to Fig. 1. In Fig. 1, the digital signal input terminal 1, supplied with an n-bit digital input signal, is connected via the DA converter 2, multiplier 3, and bandpass filter 10, to the analog signal output terminal 4. Moreover, the output stage of the clock generator 5 is connected to the DA converter 2 and the tank circuit 6. Furthermore, this tank circuit 6 is connected to the input of the said multiplier 3.

[0010] A description of its operation is given below. An n-bit (n being an integer) digital signal is supplied to the DA converter 2 from the digital signal input terminal 1. In this DA converter 2, on the other hand, according to the period of a clock signal (frequency  $f_s$ ) supplied from the clock generator 5, the said n-bit digital signal is converted into an analog signal. The frequency characteristic of the output signal of this DA converter 2, for example, consists of the characteristic shown in Fig. 4. Namely, in this Figure, the frequency characteristic of the output signal of the DA converter 2, with respect to the spectrum  $\underline{a}$  of the original analog signal, consists of a frequency characteristic as shown by the solid line; namely, the analog effective characteristic  $\underline{b}$  (dotted line) was superimposed on the signal spectrum  $\underline{c}$  (broken line), which is repeated each sampling frequency ( $f_s$ ) and has a Fourier transform of isolated rectangles.

[0011] On the other hand, a sine wave which is the fundamental wave component of the input clock signal is output when the clock signals output from the clock generator 5 are fed to the tank circuit 6. When the sine wave from this tank circuit 6 and the output signal of the DA converter 2 are multiplied together by the multiplier 3, the frequency characteristic of the aperture effect is converted, as shown in Fig. 5, a DA converter output is obtained with amplitude deterioration corrected by means of the frequency characteristic of the aperture effect. In the same Figure,  $\underline{a}$  shows the spectrum of the output at the analog signal output terminal 4 of the DA converter device shown in Fig. 1,  $\underline{b}$  shows the frequency characteristic of the frequency converted aperture effect, and  $\underline{d}$  shows the frequency characteristic of the bandpass filter 10 of Fig. 1. Here, if the tuning frequency  $\underline{f}$  of the tank circuit 6 is tuned to the n-fold (n being an integer) high

harmonic of the clock frequency  $f_s$ , and similarly as regards  $n$  times the sampling frequency  $f_s$ , with respect to amplitude distortion, correction is possible by means of the aperture effect. As a specific illustration of the constitution of this tank circuit 6, for example, the circuit constitution as shown in Fig. 9 can be realized. In the Figure, the tuned frequency of the tank circuit can easily be changed by changing the value of  $L$  or  $C$  in the circuit, and it is possible to extract the required signal component (a frequency tuned to  $n$  times ( $n$  being an integer) the clock frequency  $f_s$ ) from the clock signal which was input.

[0012] Next, a description is given, using Fig. 2, of one embodiment example of a signal generator device according to the present invention. The digital signal input terminal 1, supplied with a  $k$ -bit ( $k$  being an integer) digital signal, is connected, via direct digital synthesizer (DDS) 7, DA converter 2, multiplier 3, and band limiting filter 10, to the analog signal output terminal 4. On the other hand, the control signal input terminal 12 is connected to a variable frequency oscillator 11. The output stage of this variable frequency oscillator 11 is connected to the DDS 7, DA converter 2, and tank circuit 6; furthermore, the tank circuit 6 is connected the other side input of the said multiplier 3. The operation is described below. The DDS 7 is an element which generates an  $n$ -bit digital code signal corresponding to the frequency ( $f_s$ ) of the clock signal supplied from the variable frequency oscillator 11 and a  $k$ -bit digital code signal supplied from the digital input terminal 1. The  $n$ -bit digital code signal output from this DDS 7 is input to the DA converter 2. Except for this, the operation of this embodiment example is the same as that of the aforementioned DA converter. Here, using the DDS 7, the generation is considered of an extremely low frequency compared with the sampling frequency (clock frequency). This time, the variable frequency oscillator 11 is taken as fixed. Specifically, when the clock frequency is 20 MHz, and the frequency generated using the DDS 7 is 100 KHz, the spectrum of the output signal of the multiplier 3 becomes that shown in Fig. 6(a). In this, taking the actual required signal to be the desired wave A (19.9 MHz), it is necessary to suppress frequency components other than the desired wave A by means of the band limiting filter 10. However, it becomes difficult in actuality to sufficiently suppress the spurious component B closest to the desired

wave A, because a bandpass filter with an extremely high  $Q$  becomes necessary. For example, in the case of the spectrum of the output signal of the multiplier 3 having a characteristic as shown in Fig. 6(a), in order to obtain a spurious characteristic of -70 dBc in the output signal of the band limiting filter 10, this band limiting filter 10 has to use a 6th-order BPF of  $Q = 2000$ , which in fact is impossible in actuality.

[0013] Here, controlling the oscillation frequency of the variable frequency oscillator 11 to be 30 MHz, when the frequency generated by the DDS 7 is set to 10.1 MHz, the output spectrum of this multiplier 3 is as shown in Fig. 6(b), widening the frequency interval between the desired wave A and the spurious components, the realization of a filter in order to suppress the closest spurious component B becomes easy, and a DA converter output is obtained with few spurious signals and little noise. For example, in the case that the spectrum of the output signal of the multiplier 3 is the characteristic shown in Fig. 6(b), in the output signal of the band limiting filter 10, similarly to the abovementioned, in order to obtain a -70 dB spurious signal characteristic, this can easily be obtained with a band limiting filter 10 using a 6th order BPF of  $Q = 20$  as shown in Fig. 10. When a  $k$ -bit digital signal is supplied to the DDS 7, by changing the oscillation frequency ( $f_s$ ) of the variable frequency oscillator 11, it becomes possible to change the DA converter 2 output to a required frequency band. In this embodiment example, the variable frequency oscillator 11 may also be based on, specifically, a VCO (voltage controlled oscillator) or VCXO (voltage controlled quartz oscillator), or may be constituted using another DDS.

[0014] A description is next given, using Fig. 7, of an application of the present invention which used this embodiment example. Fig. 7 is a block diagram of an FM modulator constituted using the signal generator device shown in Fig. 2. The modulation input terminal 13 is connected to the analog signal output terminal 4 via an adder 14, DDS 7, DA converter 2, multiplier 3, and bandpass filter 10. On the other hand, the control signal input terminal 12 is connected to the other input of the multiplier 3 via the variable frequency oscillator 11, DDS 7, DA converter 2,



and tank circuit 6; furthermore, the tank circuit 6 is connected to the other input of the multiplier 3. The operation of this circuit is described below. As previously mentioned, the DDS 7 can set the frequency of the generated signal according to its clock signal and the input digital code. Here, if the data input from the modulation input terminal 13 is zero, Fig. 7 becomes a circuit equivalent to Fig. 2, the FM modulation center frequency is set at a constant  $K_w$ , and a single frequency component is output. Adding a modulation component with respect to this center frequency causes the code input to the DDS 7 to change, and FM modulation is generated by the changing of the frequency. The operation thereafter consists of the same operation as the embodiment example shown in Fig. 2, and it is possible to generate FM modulation in the required frequency band, with few spurious signals and little noise.

#### [0015] Effects of the Invention

By means of the present invention as described hereinabove, correction is performed of the amplitude-frequency characteristics in order to efficiently utilize the high frequency component of the DA converter output; and also, it becomes possible to realize a DA converter device from which a DA converter output signal is obtained having little noise which contained spurious components. Moreover, using this DA converter device, it becomes possible to realize a signal generator device which can generate a required frequency signal with low noise, and in addition, to realize an FM modulator device.

#### Brief Description of the Drawings

Fig. 1 is a block diagram showing an embodiment example of a DA converter according to the present invention.

Fig. 2 is a block diagram showing an embodiment example of a signal generator device according to the present invention.

Fig. 3 is a block diagram showing a constitutional example of a prior art DA converter device.

Fig. 4 is a diagram showing one example of the frequency spectrum in the output signal

of a DA converter.

Fig. 5 is a diagram showing the frequency spectrum in the output signal of a DA converter device according to the present invention.

Fig. 6 is a diagram showing an example of the frequency spectrum in the output signal of a signal generator device according to the present invention.

Fig. 7 is a block diagram showing an example of a practical application of the present invention.

Fig. 8 is a block diagram showing a constitutional example of a frequency modulation circuit containing a DA converter of the prior art.

Fig. 9 is a circuit diagram showing an internal constitutional example of the tank circuit in the present invention.

Fig. 10 is a diagram showing an example of the characteristic of a bandpass filter in the present invention.

#### Explanation of the Symbols

- |    |                                |
|----|--------------------------------|
| 1  | digital signal input terminal  |
| 2  | DA converter                   |
| 3  | multiplier                     |
| 4  | analog signal output terminal  |
| 5  | clock generator                |
| 6  | tank circuit                   |
| 7  | direct digital synthesizer     |
| 8  | pulse waveform shaping circuit |
| 9  | fixed oscillator               |
| 10 | bandpass filter                |
| 11 | variable frequency oscillator  |
| 12 | control signal input terminal  |
| 13 | modulation input terminal      |

- 14     adder
- a     original analog signal
- b     frequency characteristic of aperture effect
- c     DA converter output signal when aperture effect is not received
- d     frequency characteristic of bandpass filter
- a□    output signal of DA converter device shown in Fig. 1
- b□    frequency characteristic of frequency converted aperture effect
- A     desired wave
- B     spurious component

#### Captions in the Figures

- Figs. 1, 2:                6        tank circuit
- Fig. 3:                    8        pulse waveform shaping circuit
- Figs. 4, 5, 6(a) and 6(b):
- abscissa: frequency;   ordinate, amplitude
- Fig. 7:                    6        tank circuit
- Fig. 10:                   abscissa: frequency difference [?], MHz
- ordinate: amount of attenuation [?], dB

# EUROPEAN PATENT OFFICE

## Patent Abstracts of Japan

PUBLICATION NUMBER : 08204558  
PUBLICATION DATE : 09-08-96

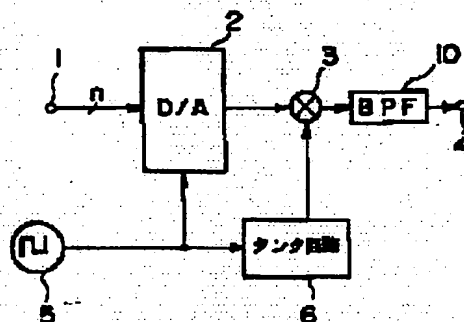
APPLICATION DATE : 25-01-95  
APPLICATION NUMBER : 07010128

APPLICANT : HITACHI DENSHI LTD;

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INT.CL. : H03M 1/08 H03B 28/00 H03C 3/00  
H03M 1/66 H03M 1/86

TITLE : DA CONVERTER



**ABSTRACT :** **PURPOSE:** To provide a DA converter, which effectively uses higher harmonics generated by sampling and lessens unnecessary spurious and noise, and the signal generator which uses this DA converter to generate a signal having a required frequency and lessens unnecessary spurious and noise.

**CONSTITUTION:** The DA converter where the frequency characteristic is corrected and harmonic components generated by sampling are effectively used by extracting the fundamental wave component of a clock signal from this clock signal given to a DA converter 2 by a tank circuit 6 and multiplying the output signal of the DA converter 2 by this extracted signal is realized. The signal generator which has less unnecessary spurious and noise and generates a signal having a required frequency by providing this DA converter and a DDS (direct digital synthesizer) 7 and changing the clock frequency given to the DA converter 2 and the frequency setting code of the DDS 7 is obtained.

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(19) 日本国特許庁 (J P)

(12) 公開特許公報 (A)

(11) 特許出願公開番号

特開平8-204558

(43) 公開日 平成8年(1996)8月9日

(51) Int.Cl. <sup>6</sup>	識別記号	庁内整理番号	F I	技術表示箇所
H 0 3 M 1/08	B			
H 0 3 B 28/00	A			
H 0 3 C 3/00	A			
H 0 3 M 1/66	C			
1/86				

審査請求 未請求 請求項の数 4 O L (全 5 頁)

(21) 出願番号 特願平7-10128

(22) 出願日 平成7年(1995)1月25日

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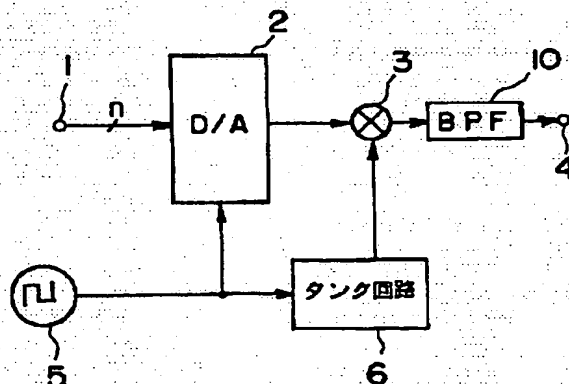
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(54) 【発明の名称】 DA変換装置

(57) 【要約】 (修正有)

【目的】 DA変換装置において、サンプリングによって生ずる高調波を有効に利用でき、且つ不要なスプリアスや雑音が少ないDA変換装置を提供する。またこのDA変換装置を用いて、所要の周波数の信号を発生でき、不要なスプリアスや雑音が少ない信号発生装置を提供する。

【構成】 DA変換器2に与えられるクロック信号から、タンク回路6を用いてその基本波成分を抽出し、この抽出した信号をDA変換器2の出力信号に、乗ずるよう構成することによって、周波数特性を補正し、かつサンプリングによって生ずる高調波成分を有効に利用できるDA変換装置を実現する。更に、このDA変換装置と、DDS7を備え、DA変換器2に与えられるクロック周波数と、DDS7の周波数設定用コードとを変えられるように構成することによって、不要なスプリアスや雑音が少なく、所要の周波数の信号を発生できる信号発生装置が得られる。



3

とDA変換手段にクロック信号を供給するクロック発生手段と、該クロック信号からその基本波成分の $n$ 倍( $n$ は自然数)の周波数成分を抽出するためのタンク回路と、該タンク回路の出力信号と上記DA変換手段の出力信号とを乗算し所要の出力信号を得る乗算手段とを備え、と共に、上記クロック信号の周波数と、上記デジタル信号発生手段における出力周波数設定コードとの各々を変更するための手段を設けたものである。

【0008】

【作用】その結果、乗算器の入力信号について、従来のパルス波形信号と比べ、タンク回路の出力信号は、スプリアス成分等の雑音成分が少ないため、乗算器の出力信号においても雑音成分を著しく低減でき、上記のように比較的簡易な構成で、低雑音で、かつアバーチャ効果による振幅劣化を補正したDA変換出力信号を得ることができる。また、このDA変換装置を利用して、低雑音で、かつ所要の周波数信号を発生できる信号発生装置を実現することができる。

【0009】

【実施例】以下、本発明によるDA変換装置の一実施例を図1を用いて説明する。図1において、 $n$ ビットのデジタル信号が供給されるデジタル信号入力端子1は、DA変換器2、乗算器3、帯域通過フィルタ10を介して、アナログ信号出力端子4と接続されている。また、クロック発生器5の出力段は、DA変換器2及びタンク回路6に接続され、さらに、このタンク回路6は、上記乗算器3の他方の入力に接続されている。

【0010】以下、この動作について説明する。デジタル信号入力端子1からDA変換器2に、 $n$ ビット( $n$ は自然数)のデジタル信号が供給される。このDA変換器2において、他方、クロック発生器5より供給されるクロック信号(周波数 $f_s$ )の周期に従って、上記 $n$ ビットのデジタル信号はアナログ信号に変換される。このDA変換器2の出力信号の周波数特性は、例えば、図4に示すような特性となる。すなわち、同図において、DA変換器2の出力信号の周波数特性は、原アナログ信号のスペクトル $a$ が、サンプリング周波数( $f_s$ )毎に繰り返された信号スペクトル $c$ (破線)に対して、孤立矩形パルスのフーリエ変換、すなわち、アバーチャ効果の特性 $b$ (一点破線)が掛けられた、実線で示すような周波数特性となる。

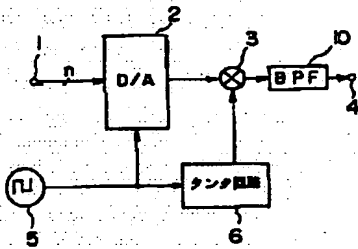
【0011】一方、クロック発生器5から出力されたクロック信号は、タンク回路6に与えられ、入力したクロック信号の基本波成分である正弦波が出力される。このタンク回路6からの正弦波と、DA変換器2の出力信号が乗算器3で乗ぜられると、アバーチャ効果の周波数特性が周波数変換され、図5に示すように、アバーチャ効果の周波数特性による振幅劣化が補正されたDA変換出力が得られるものである。同図において、 $a'$ は図1に

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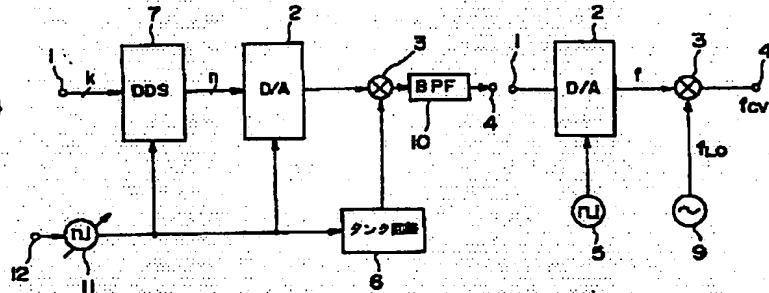
力信号のスペクトルを示し、 $b'$ は周波数変換されたアバーチャ効果の周波数特性、 $d$ は図1の帯域通過フィルタ10の周波数特性を示している。ここで、タンク回路6の同調周波数 $f$ を、クロック周波数 $f_s$ の $n$ 次( $n$ は自然数)の高調波に同調させれば、 $n$ 倍のサンプリング周波数 $f_s$ についても同様に、アバーチャ効果による振幅歪に対し、補正することが可能である。このタンク回路6の回路構成の具体例を例示すると、例えば、図9に示すような回路構成で実現することができる。図において、回路中の $L$ 又は $C$ の値を変えることによって、タンク回路における同調周波数を容易に変更することができ、入力したクロック信号から、所要の周波数(クロック周波数 $f_s$ の $n$ 倍( $n$ は自然数)の周波数)に同調させた信号成分を抽出することが可能である。

【0012】次に、本発明による信号発生装置の一実施例の実施例を、図2を用いて説明する。 $k$ ビット( $k$ は自然数)のデジタル信号が供給されるデジタル信号入力端子1は、ダイレクト・デジタル・シンセサイザ(DDS)7、DA変換器2、乗算器3、帯域制限フィルタ10を介して、アナログ信号出力端子4に接続される。一方、制御信号入力端子12は、周波数可変発振器11に接続される。この周波数可変発振器11の出力段は、DDS7、DA変換器2、タンク回路6に接続され、更に、タンク回路6は、上記乗算器3の他方の入力に接続される。以下、この動作について説明する。DDS7は、デジタル信号入力端子1より供給された $k$ ビットのデジタルコード信号と、周波数可変発振器11より供給されるクロック信号の周波数( $f_s$ )に対応して、 $n$ ビットのデジタルコード信号を発生させる素子である。このDDS7より出力された $n$ ビットのデジタルコード信号は、DA変換器2に入力される。これ以降の本実施例の動作は、前述したDA変換装置の実施例と同じである。ここで、DDS7を用いて、サンプリング周波数(クロック周波数)に比べ、非常に低い周波数を発生させることを考える。このとき、周波数可変発振器11の発振周波数は、一定であるものとする。具体例として、クロック周波数20MHz、DDS7を用いて発生させる周波数を100kHzとすると、乗算器3の出力信号のスペクトルは、図6(a)のようになる。この中で、実際に必要とされる信号を希望波A(19.9MHz)とすると、帯域制限フィルタ10により、希望波A以外の周波数成分を抑圧する必要がある。しかし、もっとも希望波Aに近いスプリアス成分Bを十分抑圧するためには、非常にQの高い帯域通過フィルタが必要となるため、その実現が困難となってしまう。例えば、乗算器3の出力信号のスペクトルが、この図6(a)に示す特性である場合、帯域制限フィルタ10の出力信号において、スプリアス特性-70dBcを得るためには、この帯域制限フィルタ10は、Q;2000の6次のBPF

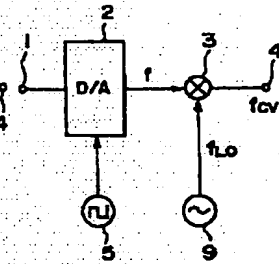
【図1】



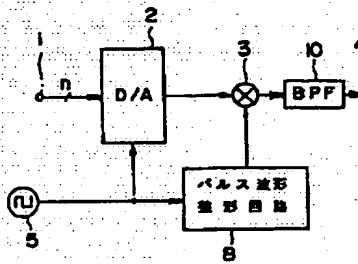
【図2】



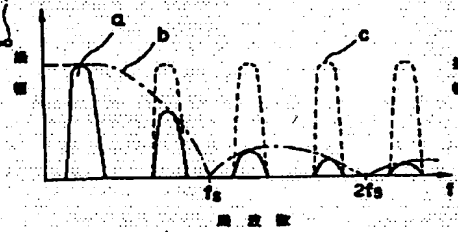
【図8】



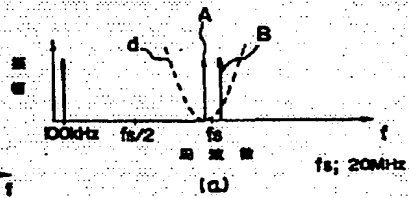
【図3】



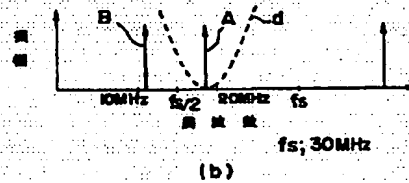
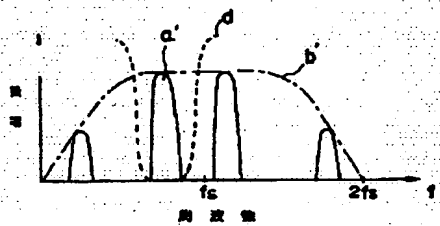
【図4】



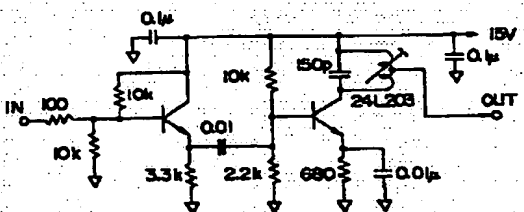
【図6】



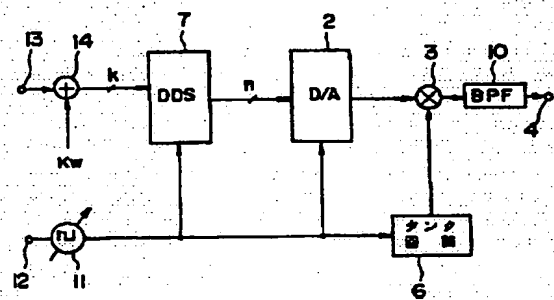
【図5】



【図9】



【図7】



【図10】

